

**Management of Textile Trade and Technology**

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**Research Project**

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**Optimization of Warp Knitted Garments Manufacturing**

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# *Research Project on Optimization of Warp Knitted Garments Manufacturing*

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## **1.0 Introduction**

In warp knitting, Fabric loops are interlocked or laid among the needles of individual yarn producing wales in vertical sequential formation along with the selvedge by various types of warp pattern and design. That knitting process increases the durability and strength of the warp knit fabrics and gives elasticity to the length. In addition, warp knitting reduces the weight of the garment because edges don't require additional process and finishing. Warp knitting represents the fastest method of producing fabrics from yarns with production range up to 4400 rpm. Any design is also done easily in warp knitting along with high productivity. This is why warp knitted garments have prosperous future possibilities in casual and sportswear fields.

The vast spectrums in high-modern textiles require different suitable production conditions and diverse phases. Considering the various raw materials and the highly specialized applications, it is obvious that the technological diversifications are also required to bring up flexibility, more efficiency, better quality and cost effectiveness in production. Therefore, in this research project our main focus is on warp knitting and consequently its technological developments like seamless warp knitted garments production. Due to some limitations we couldn't precede our project with sufficient practical experiments but we tried to figure out that how warp knitting technology serves the apparel market and its utmost development seamless technology could provide benefit for apparel world.

Seamless knitting technology creates one entire complete garment with minimal or no cutting and sewing process. This innovative technology eliminates post labor work, which saves production time and cost. In addition, the technology offers knitwear consumers more comfort and better fit in some cases by eliminating seams. Thus, seamless technology provides benefits to manufacturers as well as end users. Further, instead of being sewn in pieces, garments are knitted in full and virtually seamless. This provides athletes with improved multi-directional movement and range of motion with seamless, breathable and lightweight. This is why seamless knitting technology is entering into the mainstream of the knitwear market.

## **2.0 Abstract**

Through this research we will go through with principles of warp and seamless knitting techniques; the evolution of the knitting process, the production processes for different knitting types, advantages and disadvantages of seamless knitting and the distinctiveness among the warp, weft and seamless knitting. The aim of this project is to find out the future possibilities of warp or seamless garments and obstacles to expand in Market.

This paper will also discuss on the characteristics and applications of complete garments in warp seamless, warp cut & sewn and weft cut & sewn products. This research was accomplished through interviews from Karl Mayer Textile machine fabric GmbH, a review of practical test report and literatures. It has implications for academicians and industrial personnel who require information in detail for knitting technology and knit products.

Since the introduction of seamless garment knitting techniques on V-bed machines in 1995, this technology has been considered an innovative process and is growing currently in its commercial application around the world. Hereby, It is demonstrated that how does the seamless garment knitting provide a variety of advantages in knitting productions.

### 3.0 History

In the year 1527, the first knitting association was started in Paris. Seamless entire garment knitting was introduced in 1995, at ITMA, the International Textile Machinery Association. In the following table, the consequence of knitting technology day by day developments is figured out:

<b>Year</b>	<b>Historical Events Contributing to Development of Seamless Knitting</b>
1589	William Lee in England invented the first flat-bed frame to create hosiery.
1863	Issac W. Lamb invented the first operational V-bed flat knitting machine including the latch needles.
1864	William Cotton of Laugh borough patented his rotary-driven machine that used a flat bed to produce fully-fashioned garments
1800'S	The flat knitting machine was fitted with sinkers which controlled stitches in order to knit single jersey tubular articles such as gloves, socks and berets.
1940	The manufacture of shaped knitted skirts using a "flechage" technique was patented in the USA.
1955	The Hosiery Trade Journal reported on the automatic knitting of traditional berets through the shaped sections.
1960'S	Shima Seiki company further explored the tubular-type knitting principle to produce gloves commercially.
1960'S	Courtaulds established British patents on the idea of producing garments by joining tube knitting <sup>1</sup> .
1980	First double needle bar Raschel machines with Jacquard system were built by Nippon Mayer, Japan (mainly for production of panty stockings).
1995	Shima Seiki introduced seamless entire garment knitting at ITMA.
1999	First deliveries of RDPJ 6/2 (Raschel Double Piezo Jacquard), 138", E24 with electronic Piezo Jacquard system.
2008	Introduction of DJ 4/2, 44", E24
2009	Introduction of DJ 6/2, 44", E28 with electronic pattern drive system (EL). (total machine population of DJ-series 2012: ~25 machines)
2010	Introduction of DJ 4/2, 44", in finer gauge: E32
2011	Introduction of PPD on DJ series <sup>2</sup> .

**Table 1: Historical events contributing to development of seamless knitting.**

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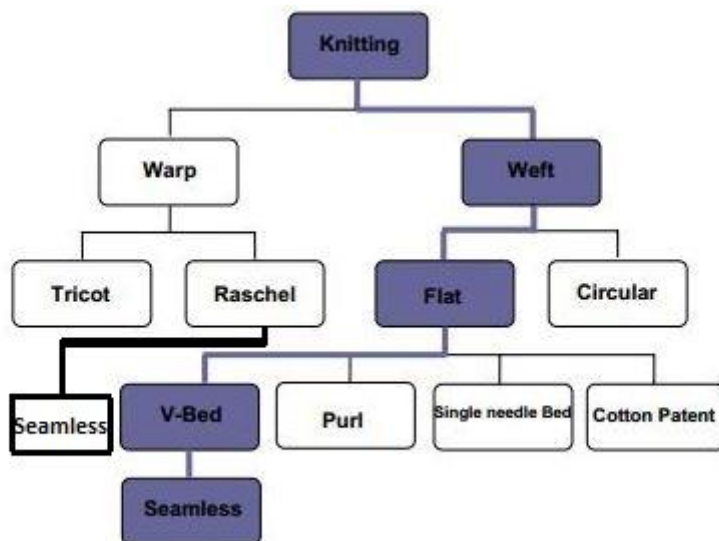
<sup>1</sup> <http://www.fibre2fashion.com/industry-article/pdf/Three-Dimensional-Seamless-Garment-Knitting.pdf?PDFPTOKEN=d49febc36a060e80ffd710fa34c362c8aea2c481>.

<sup>2</sup> From Karl-Mayer, Mr. Roland Baempfer

## 4.0 Objectives

1. To find out the Productive, cost effective and prospective apparels from the warp knitting field.
2. Find out the future development possibilities of warp knitting technology by reviewing manufacturing process, machineries, costs, production time and designs.
3. Garment and Fabric quality analysis for Warp knitted products.
4. Garments fitting performance analysis between Cut & Sewn garments and seamless garments.
5. To learn about the quality parameters that affect garment quality.
6. Minimize the fabric consumption in garments production.
7. To learn the optimum selection of knitting process according to end-use.
8. How to develop the market value of warp knitting by analyzing product cost.
9. To analyze the warp knitted garments performance compared to weft knitted garments.

## 5.0 Classification of knitting

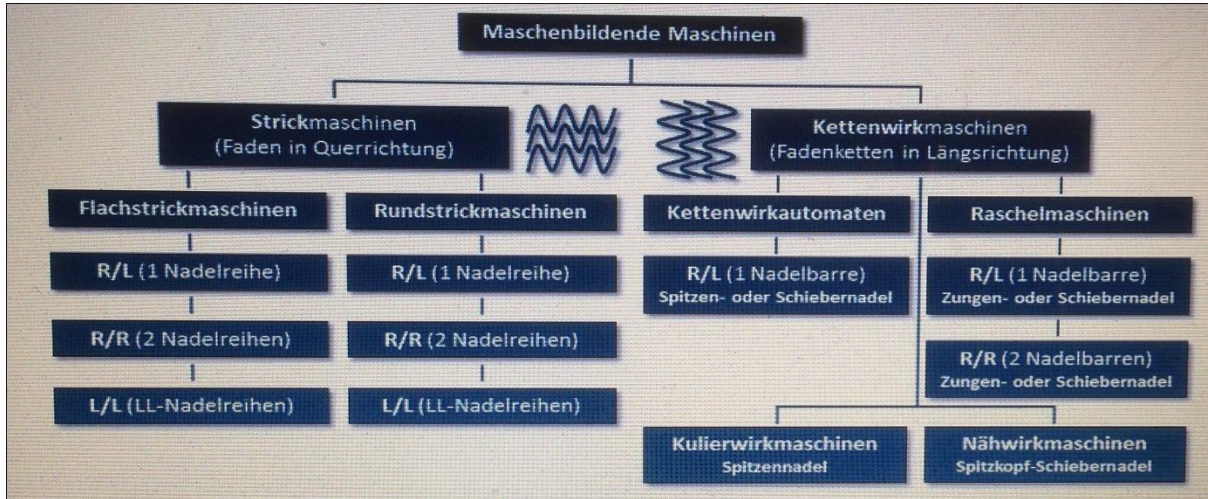


**Fig-1: Knitting Classification Diagram**<sup>3</sup>

<sup>3</sup> <http://www.fibre2fashion.com/industry-article/pdffiles/Three-Dimensional-Seamless-Garment-Knitting.pdf?PDFPTOKEN=d49febc36a060e80ffd710fa34c362c8aea2c481>.

## 5.1 Knitting Classification according to machineries

Deutsch version (main):



English version (Translated):

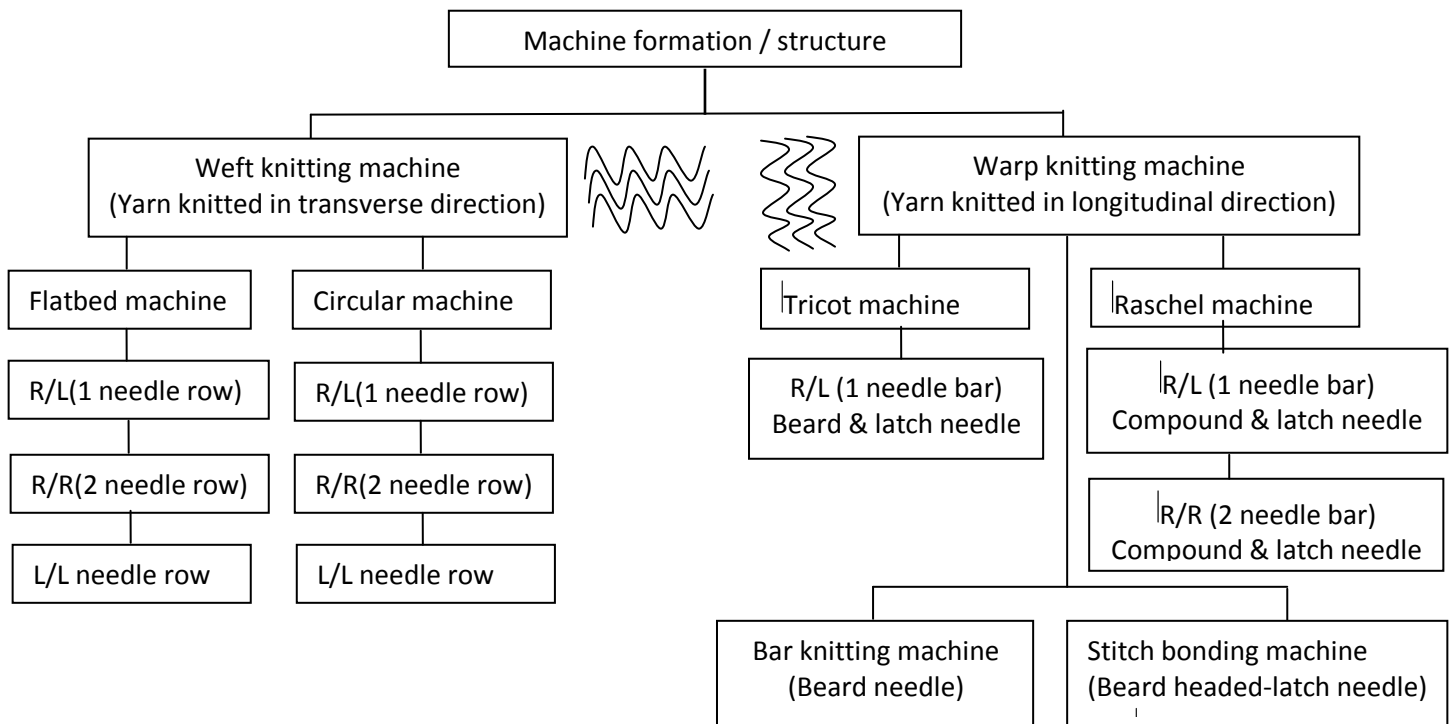


Fig-2: Diagram for knitting m/c classification <sup>4</sup>

<sup>4</sup> From Karl-Mayer, Mr. Roland Baempfer

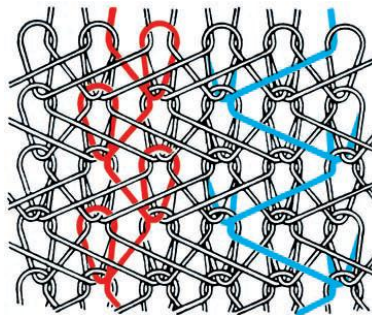
## **6.0 Applications of Warp knitting <sup>5</sup>**

For most warp knitted fabrics, the basic lapping structures are used in combination. This means that more than one warp sheet and guide bar must be used. Warp knitted fabrics have only a limited range of applications in apparel fabrics. The most important are: leisure, sportswear and swimwear, foundation and lingerie, extensible linings, laces, ribbons and trimmings.

In household textiles, warp knits are used for curtains, bed clothing and furnishings. The widest use of warp knits is in technical fabrics. The most common usages of warp knitted product are given below:

### **i. Locknit :**

Locknit (charmeuse) is a combination of tricot 1x1 and 2x1 plain stitches. On one side the fabric plays distinct wales of small face loops (red loops in Fig 3); the other side shows the zigzag formation of the under laps.



**Fig 3: Locknit**

It is made from filament yarns which give the characteristic luster. Applications: linings, interlinings, lingerie.



**Fig 4-5:- Bangladesh made Tricot jersey for Football world cup 2014**

(Home-team Brazil is wearing jerseys made in Bangladeshi factories with the tag "Made in Bangladesh")



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### **ii. Warp Knitted Terry**

This is made with an extra warp sheet of pile yarns which are caused to form loops, bound into a ground fabric. Applications include furnishings and bed sheets (Figure 6).



**Fig 6: Warp knitted terry**

### **iii. Warp Knitted Plush, Velour**

In this case, the pile loops are cut to give a fleecy or velvet-like surface. Applications include beach, leisure and sportswear, ladies outerwear (Figure 7).



**Fig 7: Warp knitted plush, velour**

### **iv. Raschel Net**

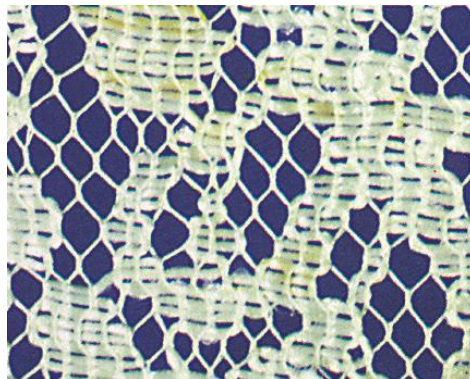
Nowadays, net fabric is almost always made on raschel machines. It is a combination of pillar and tricot stitches. Raschel net is most popular in bridal wear (Figure 8).



**Fig 8: Raschel net**

**v. Raschel Lace**

Raschel lace fabrics are often made on a base of net fabric with a pattern formed from inlay yarns. They are used for foundation and lingerie, bridal and formal wear, and as trimmings (Figure 9).



**Fig 9: Raschel lace**

## **7.0 Applications of Seamless knitting <sup>6</sup>**

- a. Seamless knitted goods are mainly used for apparel. This new three-dimensional knitting technique has been extended in other areas such as fashion, upholstery, industrial, automotive, and medical textiles.
- b. Apparel: Hand gloves, Hats, Socks, Sweaters, Trousers, Skirts.
- c. Upholstery: Office chairs.
- d. Automotives: Seat covers.
- e. Medical textiles: bandages, orthopedic supports, and medical compression stockings.
- f. The incorporation of high performance fibers and additional sensors or electronics could provide further opportunities for seamless products in healthcare applications.

These products are mainly to be found in the underwear sector, particularly in a percentage of total seamless products:

- Ladies' underwear (78%)
- Men's underwear (13%)
- Outerwear (2%)
- Swimwear (2%)
- Sportswear (4%)
- Sanitary products (1%)

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<sup>5</sup> [http://content.schweitzer-online.de/static/content/catalog/newbooks/978/380/856/9783808562253/9783808562253\\_Excerpt\\_004.pdf](http://content.schweitzer-online.de/static/content/catalog/newbooks/978/380/856/9783808562253/9783808562253_Excerpt_004.pdf), Page – 93.

<sup>6</sup> <http://www.indiantextilejournal.com/articles/FAdetails.asp?id=4426>

## **7.1 Underwear / Lingerie wear**

It is an item of clothing that privileges the seduction and eroticism dimensions, realized and exalted by the SANTONI SEAMLESS technology. The Graphic software allows unlimited creative process, creating transparencies, particular knit points played with a glamorous ambiguity<sup>7</sup>.



**Fig 10: Lingerie wear<sup>8</sup>**

## **7.2 Swimwear / Beachwear**

The swimwear becomes the body wrapping, a second skin who exalts the body shape, supporting wherever necessary thanks to the high performance IN fibers and dry fit yarns<sup>9</sup>.



**Fig 11: Swimwear / Beachwear<sup>10</sup>**

### **7.3 Sportswear / Active wear**

The seamless sportswear lends to the free time look, performance and aesthetic qualities who exalts the body anatomy by using high performance fabrics with graduate compressions.

Ergonomic and micro massage garments, protective and smart garments for a different way of conceptual wear <sup>11</sup>.



**Fig 12: Sportswear / Active wear** <sup>12</sup>

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<sup>7</sup> <http://www.santoni.com/en-areeprodotto1.asp>

<sup>8</sup> From Karl Mayer, Mr. Roland Baempfer.

<sup>9</sup> <http://www.santoni.com/en-areeprodotto2.asp>

<sup>10</sup> <http://www.santoni.com/videofoto.asp>

<sup>11</sup> <http://www.santoni.com/en-areeprodotto3.asp>

<sup>12</sup> From Karl Mayer, Mr. Roland Baempfer.



## *Zero fit - Men's sports shirt with functional zones*



- Slight compression effects
- High elastic line on the back allows free movement and improves the shoulder posture
- No skin irritation, as no seams in the range of motion
- Moderate pressure will reduce fatigue controlling the vibration of muscles

Zero fit is made with seamless 173-400% elasticity in tension and natural comfortless according to different body movements and functions.

## *Net stockings*

- Use of different lappings/ patterns for the front and back of garments



## **7.4 Outerwear / Knitwear**

The Seamless outwear Santoni open new interpretative modes and create to the consumer a realization played on a combination of factors aesthetic/practical and perceptive/symbolic.

The products realized with high performance fibers allow the use for different occasions, the expression of a new way to dress today <sup>13</sup>.



**Fig 13: Outerwear / Knitwear** <sup>14</sup>

## **7.5 Home wear / Nightwear**

Garments realized for the need to live the domestic rituality with comfortable and practical products. Garments to wear in relax and private moments <sup>15</sup>.



**Fig 14: Home wear / Nightwear** <sup>16</sup>

<sup>13</sup> <http://www.santoni.com/en-areeprodotto4.asp>

<sup>14</sup> From Karl Mayer, Mr. Roland Baempfer.

<sup>15, 16</sup> <http://www.santoni.com/en-areeprodotto5.asp>

## **7.6 Medical wear / Shape wear**

The use of the seamless Technology in the production of the medical wear has produced undisputed aesthetics and healthy advantages for the body Massaging and shaping products Protective products pre/post stay in Hospital Compressing garments pre/post child birth <sup>17</sup>.



**Fig 15: Medical wear / Shape wear** <sup>18</sup>

## **8.0 Market Condition & Growth rate of Seamless Garments**

The SEAMLESS concept spread all over the world with a surprising quickness. Within only three years the seamless underwear products reached in 2001, 9% of the global production in the industrial segment, compared with the quote of 2% reached in 1998, with an exponential growth of 18% in 2003. In 2007 the forecast indicated an increase of 35% in the same underwear industrial segment <sup>19</sup>.

Cifra is the highly innovative seamless line, which ranges from t-shirts to lingerie wear, to gloves and tights then finishing with sportswear, is completely created on WARP KNITTING machines <sup>20</sup>.

In a sensational deal announced today, two of the world's market leading manufacturers of knitted seamless apparel are to collaborate to produce a new line of unique lingerie, body shapers, posture garments and sportswear products based on seamless warp knitting technology. **Tefron** is the global leader in engineered seamless apparel. With its 24 hour production schedule, this Italian company has the capacity to produce 150,000 pairs of stockings alone per day on its raschel machines. Tefron lists amongst its customers leading international players such as Hanes Brands, Reebok, Patagonia, GAP, Calvin Klein, Wal-Mart and Victoria's Secret. The new agreement should

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result in a win-win situation for both companies. Tefron will be the only major design led company worldwide which can offer its customers both warp and weft knit seamless solutions.

Warp knit seamless has many possibilities which weft knit seamless cannot offer. Warp knit seamless technology for example offers the possibility to produce complex lace and openwork type structures as well as a wide range of fancy patterns at high production rates <sup>21</sup>

Seamless garments are the fastest growing segment of the intimate apparel business and will likely account for 50% of the industry's \$12 billion sales within the next ten years. Recent figures suggest that seamless intimate apparel has captured around 6% of the total market in the last five years. With the U.S.A as its primary market, Tefron controls about 30% of the burgeoning business for seamless underwear <sup>22</sup>.

### **8.1 Market reaction to the functional warp-knitted seamless items**

With special characteristics, the items produced on the RDPJ and DJ, which are setting the trend in fishnet stockings, lingerie, outerwear, medical textiles and sportswear. For example, collections developed by Cifra, Shiseist, Leonisa, Zero fit and mash mania already impress the market. Manufacturers are particularly interested in the possibilities of combining functional zones and specific compression/control characteristics. Conventional methods for working zones with different levels of stretch in the fabric involve using different types of materials, which are combined in intricate and complex designs. This method involves a great deal of time and effort to procure the materials, incurs high production costs, and produces seams that are uncomfortable when the garment is worn <sup>23</sup>.

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<sup>17</sup> <http://www.santoni.com/en-areeprodotto6.asp>

<sup>18</sup> <http://www.medsuppliessource.com/supplybrand.cfm?SUPPORT-STOCKINGS=JOBST-ELVAREX-SEAMLESS-GLOVEREADYTOWEAR-SIZE-5-BEIGE>

<sup>19</sup> <http://onlineitma.fibre2fashion.com/santoni/profile.asp>.

<sup>20</sup> <http://www.cifra-spa.net/en/products/warp-knitting-seamless-wks>.

<sup>21</sup> <http://www.innovationintextiles.com/warp-weft-cifra-tefron-in-seamless-partnership/>.

<sup>22</sup> <http://www.tefron.com/intimate.asp?ID=1>

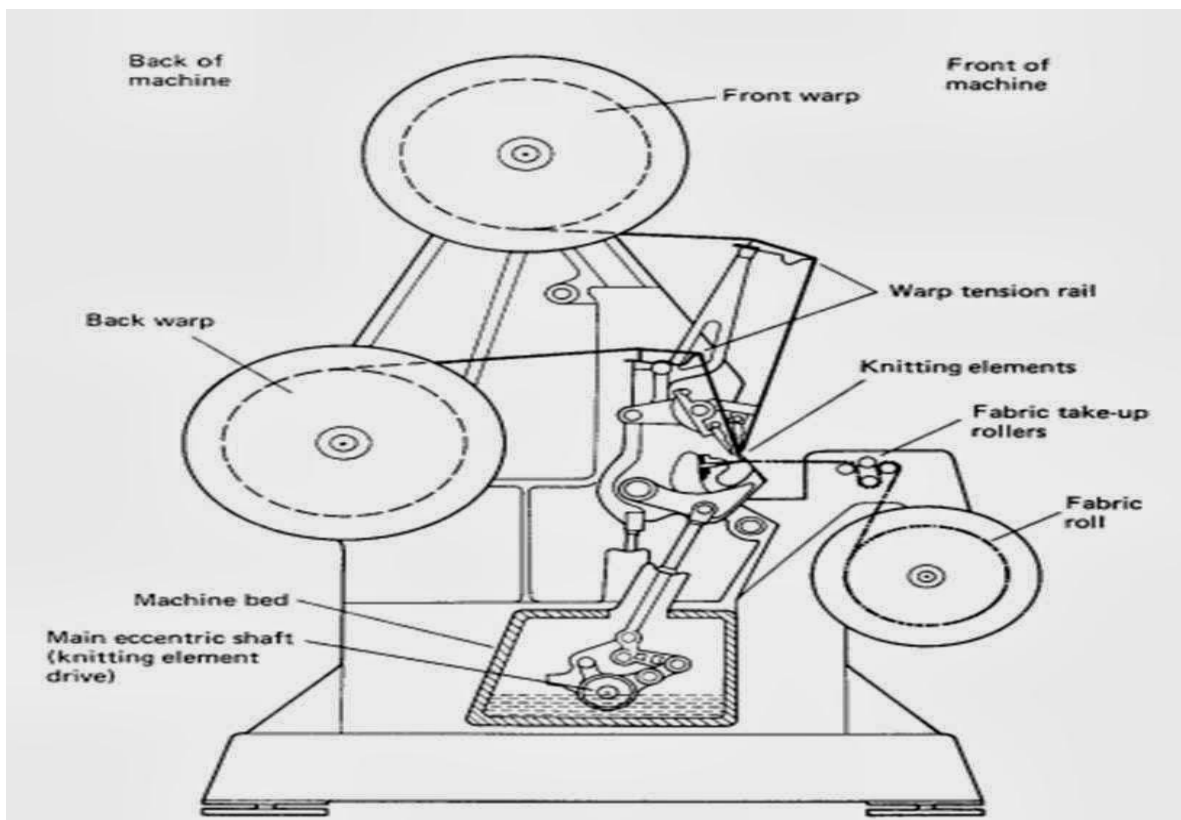
<sup>23</sup> <http://www.karlmayer.com/internet/en/kmweltweit/4582.jsp>



## 9.0 Pattern and structure for warp knitting technology

### 9.1 Machine elements and construction

In warp knitting, every knitting needle is supplied with at least one separate yarn. In order to connect the stitches to form a fabric, the yarns are deflected laterally between the needles. In this manner a knitting needle often draws the new yarn loop through the knitted loop formed by another end of yarn in the previous knitting cycle. There are two types of warp knitting machines: Tricot and Raschel which are distinguished for their sinker arrangement, Tricot has only one sinker with horizontal take up direction. Beard and compound needles are mostly used in Tricot, where Raschel has two sinkers for different purposes like knocking over and holding down, vertical or 170° take up direction and latch needle is mostly used in Raschel. Raschel machines can process all yarn types in all forms (filament, staple). But Raschel machines are little bit slower than Tricot machines.



**Fig 16: Cross-section of a bearded needle tricot machine <sup>24</sup>.**

Here is the most important knitting elements including warp beam, needle bar, Sinker, tension rail, etc.

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<sup>24</sup> [http://3.bp.blogspot.com/-hArYs\\_OSC4A/UmihN3GgI/AAAAAAAAAhc/IhJ3i\\_Qc2w/s1600/Fig%2B24.2.jpg](http://3.bp.blogspot.com/-hArYs_OSC4A/UmihN3GgI/AAAAAAAAAhc/IhJ3i_Qc2w/s1600/Fig%2B24.2.jpg)



Lapping Diagram



Closed loop



Open loop

**Fig 17: Lapping Diagram with closed and open loops**<sup>25</sup>

## 9.2 Division of pattern drives<sup>26</sup>

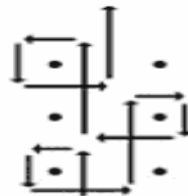
1. Mechanical pattern drives
  - Pattern drum with pattern chains
  - Pattern discs
2. Electromechanical pattern drives
  - Summary drive
3. Electronic pattern drives
  - EL pattern drives

Pattern chain link drives are now very few used in bulk productions but can be used for small quantity sample productions. From 2008, especially pattern discs and increasingly electronic pattern drives are used in practical operation. EL pattern drives used for zoned garments and lapping changes.

### **Pattern Chain link arrangement:**

The guide bar is positioned with the follower roller on chain link 0'; it swings through, then moves to the left as the roller moves to chain link 1'. It swings back and returns to its starting position (chain link 0'). The chain should read: 0 1 in the opposite direction: 1 0 the smallest repeating unit (repeat) extends over one course: height repeat = 1 stitch, width repeat = 1 stitch.

The stitch is open when the feet do not cross and closed when the feet cross. The structure of a warp knitted fabric depends on the lapping motion of the guide bars, and therefore the structure could be represented by: Drawing a stitch or stitch chart diagram or Lapping diagram.



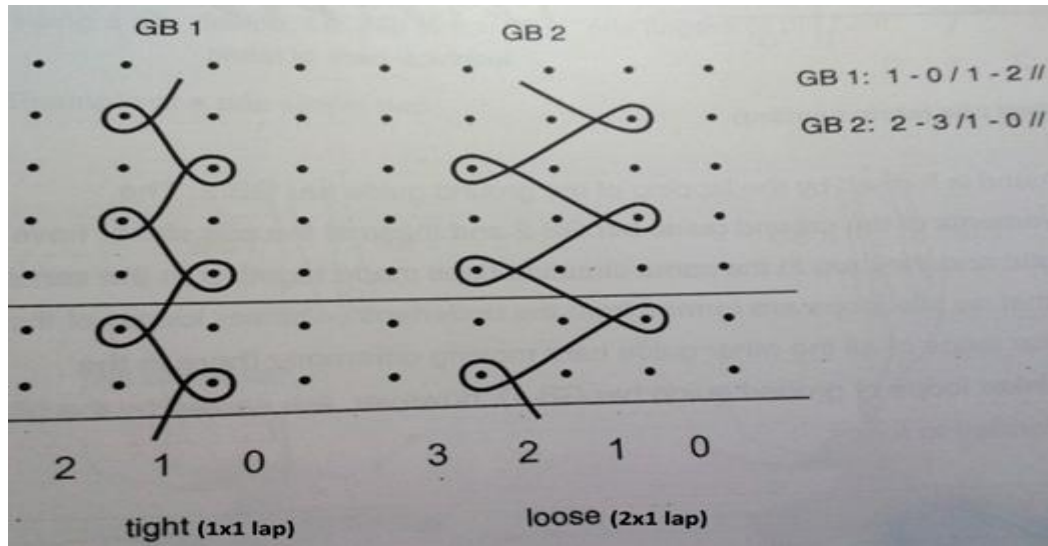
**Fig 18: Closed loop lapping**<sup>27</sup>

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<sup>25, 26, 27</sup> From Karl Mayer, Mr. Roland Baempfer.

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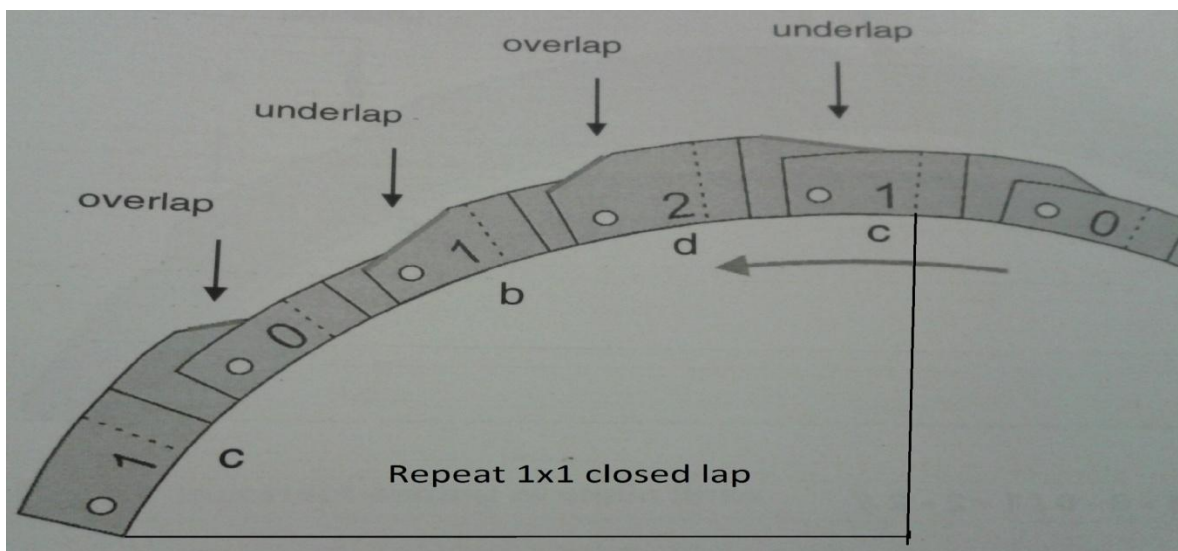
**Warp knitted fabric construction analysis:** We analyzed Lock knit fabrics and got below structure as well as pattern chain construction. In this structure guide bar-1 is 1x1 lapping system and guide bar-2 is 2x1 lapping system (Fig-19). We also saw other structures and their pattern chain systems like Satin fabric, Reverse lock knit fabric, Queen's cord fabric, Elasticated tricot fabric (polyamide swim wear) but Locknit structure is one of the most used for industrial purpose<sup>28</sup>.



**Fig 19: Lock Knit Fabrics lapping Diagram (Tricot)<sup>29</sup>**

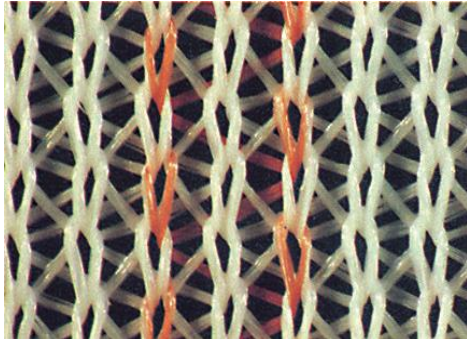
Front Guide bar: 1-0 / 1-2//

Back Guide bar: 2-3 / 1-0//

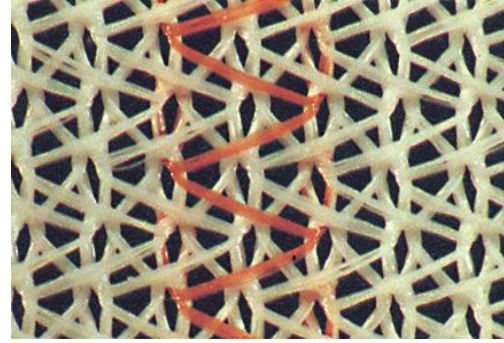


**Fig-20: Pattern chain for 1 - 0 / 1 - 2 //<sup>30</sup>**

<sup>28, 29, 30</sup> From Karl Mayer, Mr. Roland Baempfer.



**Fig- 21: Locknit face**



**Locknit back** <sup>31</sup>

The length of the under lap is defined in terms of needle spaces. The longer the under lap, the more it lies at right angles to the fabric length axis. The longer the under lap for a given warp the greater the increase in lateral fabric stability, conversely a shorter under lap reduces the width-wise stability and strength and increases the lengthways stability of the fabric. The length of the under lap also influences the fabric weight. When knitting with a longer under lap, more yarn has to be supplied to the knitting needles. The under lap crosses and covers more wales on its way, with the result that the fabric becomes heavier, thicker denser and high GSM <sup>32</sup>.

### **9.3 Most common fabrics for warp knitted Tricot**

Flat stockinet stitch is the most common texture for the knitted garment and knit stitches worked flat that used for machine made stockings and T-shirts. Simple textures are made using knit and purl stitches, garter stitch, ribbing and moss and seed stitches. There is more number of complicated patterns in which slip stitch and heel and linen stitches are used. Small eyelet holes can also be created in the fabric. Common warp knitted fabrics are -

- a) Lock knit tricot fabric
- b) Satin fabric
- c) Reverse lock knit fabric
- d) Queen's cord fabric
- e) Elasticated tricot fabric (polyamide swim wear)

### **9.4 Most common fabrics for warp knitted Raschel**

- a) Marquissette
- b) Diamond <sup>33</sup>

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<sup>31</sup> [http://content.schweitzer-online.de/static/content/catalog/newbooks/978/380/856/9783808562253/9783808562253\\_Excerpt\\_004.pdf](http://content.schweitzer-online.de/static/content/catalog/newbooks/978/380/856/9783808562253/9783808562253_Excerpt_004.pdf), Page – 93.

<sup>32</sup> <http://www.textileschool.com/School/Knitting/WarpKnitting.aspx>

<sup>33</sup> Dr. S. Raz, Warp knitting production, pp- 111-120,

## **10.0 Warp Knitting technology Developments to seamless machineries**

Cifra is one of handful of companies in the world which has exploited the true potential of warp knit seamless technology to date. The machine technology was also developed by Karl Mayer along with its Japanese subsidiary Nippon Mayer but the past few years have seen greater interest in the technology after the addition of piezo jacquard technology extended the patterning and shaping potential.

Cifra runs a plant of mainly multi head double needle bar jacquard raschel machines which knit multiple garments simultaneously side by side. In recent years Karl Mayer introduced the short needle bar Seamless Smart concept where 'smaller footprint' machines such as the RDPJ 4/2 and RDPJ 6/2 models are said to offer shorter set up times, greater flexibility in production as well as minimized machine costs. Cifra has been evaluating this technology.

Proof of the importance of the technology came when Italian machine builder Santoni, pioneer and world leader in the development of seamless circular knitting machines, recently entered into the warp knit seamless machinery market. In June 2008 the Lonati (Santoni) Group owned company, with a weft knitting background, shocked the knitting world when it launched its first 'user friendly' double needle bar raschel machine for seamless garments, the SDW8. Santoni has been busy developing the technology which Cifra has also been evaluating.

The new Tefron-Cifra partnership looks really promising as the market, via Tefron and its customer base, will have access to some of the world's best seamless warp knit know-how and the very latest technology<sup>34</sup>.

## **11.0 Seamless Knitting Machines<sup>35,36</sup>**

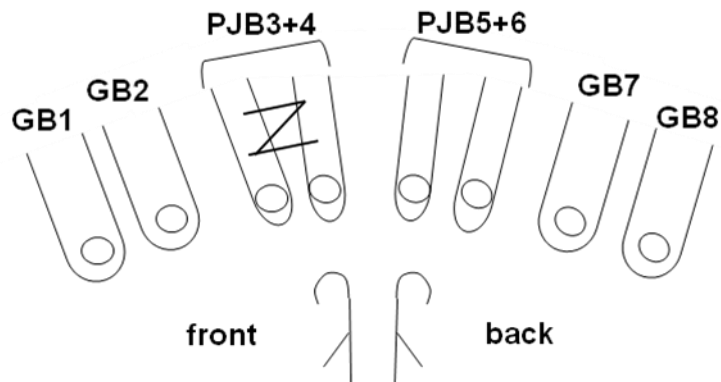
1) Santoni is now known as the one of the world leader in seamless machine manufacturing.

- They have produced the seamless warp knitting machine with the model of SDW 8. It is a double needle bar Raschel machine contains 8 guide bars with a working width of 44 inches.
- This machine can form 2 seamless garments side by side in a chain formation, which can be separated later by cutting.

2) The new machine produced from KARL MAYER, called "Seamless Smart" is designated as 'DJ' series.

*DJ 6/2 – DJ 4/2 + RDPJ*

DJ = Double needle bar Jacquard Raschel machine



**Guide bar arrangement of DJ 6/2**

- 4 Ground Guide Bars (GB1, GB2, GB7 and GB8)
- 2 Piezo-Jacquard Bars in split execution (PJB3 + PJB4, PJB5 + PJB6)
- 2 individual latch needle bars
- 2 Knockover comb bars
- 2 stitch comb bars

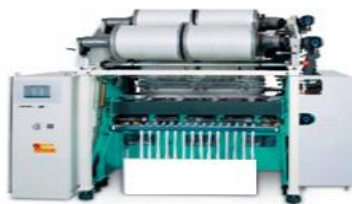
**Fig 22: Guide bar arrangement of DJ 6/2**

- The very first machine in this series is DJ 4/2, developed by Nippon Mayer Ltd.
- The working width of this machine is 42", can operate at a rate of 1,000 stitches/minute

*DJ 4/2 – DJ 6/2*

*small version*

*44"*



*RDPJ 4/2 – RDPJ 6/2*

*wide version*

*138"*



**DJ 4/2 (EL) – DJ 6/2 (EL) Seamless Smart**

Technical information	DJ 4/2 (EL)	DJ 6/2 (EL)
➤ Working widths:	44"	44"
➤ Gauges:	24E; 28E; 32E	24E; 28E; 32E
➤ Piezo-Jacquard bar in split execution	2	2
➤ Ground guide bars:	2	4
➤ Yarn let-off device: (with Multispeed)	4	6

3) The Shima Seiki company invented the Whole Garment machine and introduced the commercial complete garment knitting (SWG-V machine) in 1995 at ITMA (International Textile Machinery Association).

- Electronic WARP knitting machine for seamless item (panty house, underwear and outwear garment).
- Double needle bed bars/maximum working width 44 inch - 1,118 mm.
- Four guide bars.
- Stitch comb sinker bars.
- Gauge: GG.24 and GG.28 - compound, needles.
- Number of beams: 8 beams of 21".
- Electronic drive feeding devices for warp yarns.
- Electronic take-down device.
- Main motors brushless KW 3, 9/Voltage: 220V - 440V 3 phases.
- Other voltages available on request.
- Electronic patterning by means of PIEZO elements.
- Maximum speed: up to 700 strokes per minute.
- Production: underwear and outwear garment.
- Weights: fully loaded beam jam about kg 5,100
- Approx. dimensions (Area ~ 7 mq): Front = 2,300 mt; Side = 3,110 mt; H = 3,200 mt.
- Compressed area consumption: 30 nL (liters/1').
- Normative: Machine according to CE normative and UL compatible.

<sup>34</sup> <http://www.knittingindustry.com/warp-weft-cifra-tefron-in-seamless-partnership/>

<sup>35</sup> From Karl Mayer, Mr. Roland Baempfer.

<sup>36</sup> <http://www.indiantextilejournal.com/articles/FAdetails.asp?id=4426>



## 11.1 Advantages of DJ / RDPJ on Textile Applications <sup>37</sup>

- Well-defined hole structures (Jacquard)
- Functional zones with varying elongation and stitch density
- Different lapping / stitches & yarns on front and rear side
- Various SHAPED tube sizes produced on a single machine
- Bare elastane in several lapping/ stitch variations
- Processing of inelastic (rigid) yarns in the Jacquard



## 12.0 Who's using seamless garments?

ACME MCCRARY, ADIDAS, ALLEN COX, ARISTOC, BODY LINE, DUPONT ESCADA, FILA, FALKE, GALLIGAN & O'MALLEY, GAP, GARDA, GASSOL, HUGO BOSS, JOCKEY, JC PENNY, LACOSTE, MARCO POLO, MARKS & SPENCER, MICO SPORT, PHILIPPESA PARIS, PRADA, PUMA, REEBOK, SCALA, S.OLIVER, TARGET, TOMMY HILFIGER, TECSO, X-STATIC, ZARA <sup>38</sup>.

<sup>37</sup> From Karl Mayer, Mr. Roland Baempfer.

<sup>38</sup> <http://www.santoni.com/en-seamlessusers.asp>



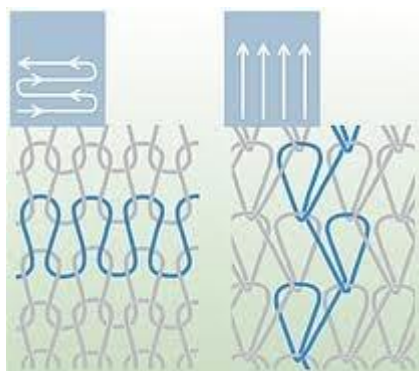
### **13.0 Properties of Warp Knitted Cut & Sewn Products**

Although warp knit fabrics can be made with high elasticity, for tailored fabrics they are made so as to have minimum extensibility and maximum stability. Therefore their properties are nearer to those of woven's rather than weft knits.

Due to their stability the warp knits are easier to handle than weft knits in garments fabrication. Shorter time is required to allow the fabric to reach its relaxed dimensions and therefore laying for cutting is easier. The fabric is not easily distorted and therefore seaming of the fabric is also easier. But warp knitted fabric faults are permanent and cannot be repaired. The products are extremely strong warp knits with high square measures as well as delicate, also stretchable textiles, grid structures and voluminous fabrics<sup>39</sup>.

### **14.0 Distinguishment of Warp and Weft Knitting<sup>40, 41</sup>**

In Case of Warp Knitting, it knits the next stitch with the same yarn always on next course. For Weft, it knits with the next stitch with the same yarn is always on same course.



**Fig-23: Circular vs. Warping Knitting**

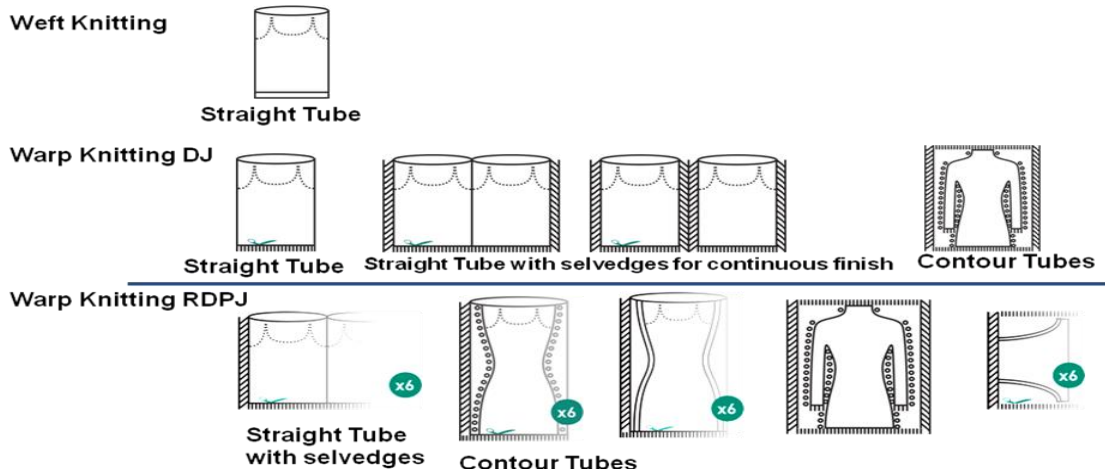
The process of casting begins on a piece of knitting. It is the creation of stitches on the needle. Different methods of casting on are used. Thumb method and double needle method are the various methods are used in cast on.

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<sup>39</sup> International Federation of Knitting Technology by K.D.Darlington, Scottish Woolen Technical College.

<sup>40</sup> <http://ezinearticles.com/?The-Basics-of-Knitting&id=1201659>

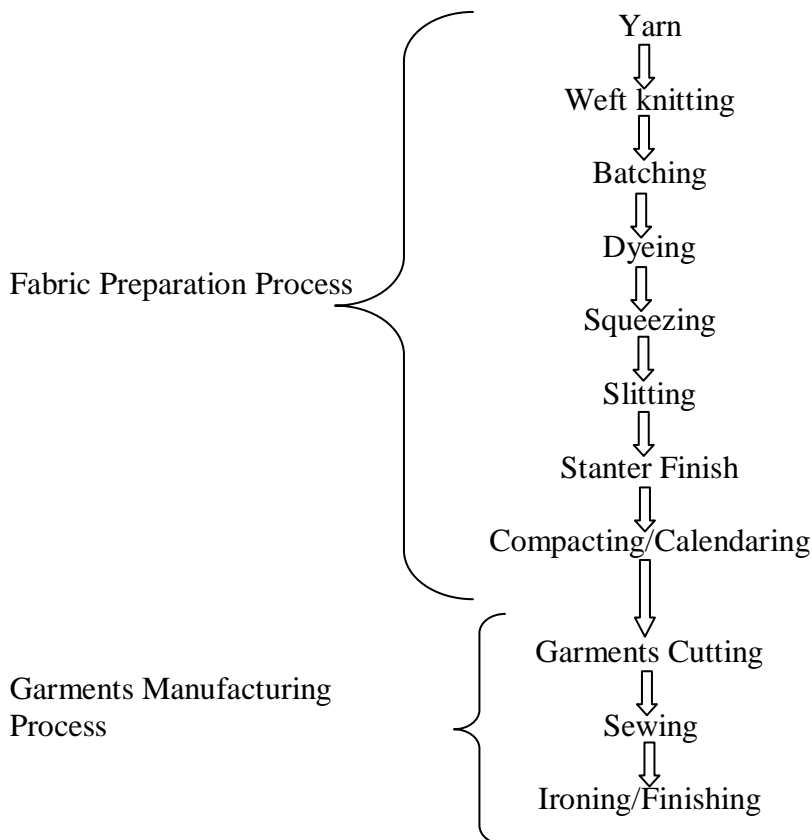
<sup>41</sup> <http://www.fairystonefabrics.com/page.aspx?p=18>



**Fig 24: Possible tube variations** <sup>42</sup>

## 15.0 Weft Knitted garments manufacturing process

Weft knitting is suitable for both natural fiber and synthetic fiber fabrics. The weft knitting process sequence is given as below:



<sup>42</sup> From Karl Mayer, Mr. Roland Baempfer.

## **16.0 Warp knitted garments manufacturing process**

Warp knitting concept started with only synthetic fibers but now natural fiber blends are also growing up in this field. Polyester and polyamide are the most common used fibers for warp knitting and wool or fine cotton blends with them also being popular now. Textured yarn for warp knitting also gives the excellent performance to produce smooth, strong and quality fabrics.

### **16.1 Texture Yarn**

The use of yarn also changes the appearance of the garment. If the yarn is thick, the stitches will be more visible and if the yarn is thin, the texture will be finer <sup>43</sup>.

A polyester textured yarn is a continuous filament yarn that has been processed to introduce durable crimps twists, interlaces, loops or other fine distortions along the lengths of the filaments. Polyester Textured Yarn made from thermoplastic materials that can be textured by heat setting in a twisted condition, and result in a polyester textured yarn of greater bulk, higher stretch, and more pleasing aesthetics <sup>44</sup>.

#### **Typical Physical properties of 150/36 textured polyester yarns <sup>45</sup>**

Properties	Autoclave set
Denier	174
Tenacity	3.6 GPD
Elongation	25%
ITIAL modulus	20
Boiling Water	2.6 %
350° F-dry heat	5.8 %
Bulk Level: C.C/GM @.15psi	16.2
Torque index	9

### **16.2 Production criteria**

For maximum resistance to snagging it is necessary to make flat surfaced yarn structures. These are easily produced on tricot and Raschel machines from 2 fully threaded guide bars.

A smooth surfaced and stable fabrics result when the guide bars knit, e.g.

Back 3-4/1-0

Front 1-2/1-0

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<sup>43</sup> [http://www.ca-bc.com/zip\\_internacional/usedmach/education/processes/knitting.html](http://www.ca-bc.com/zip_internacional/usedmach/education/processes/knitting.html)

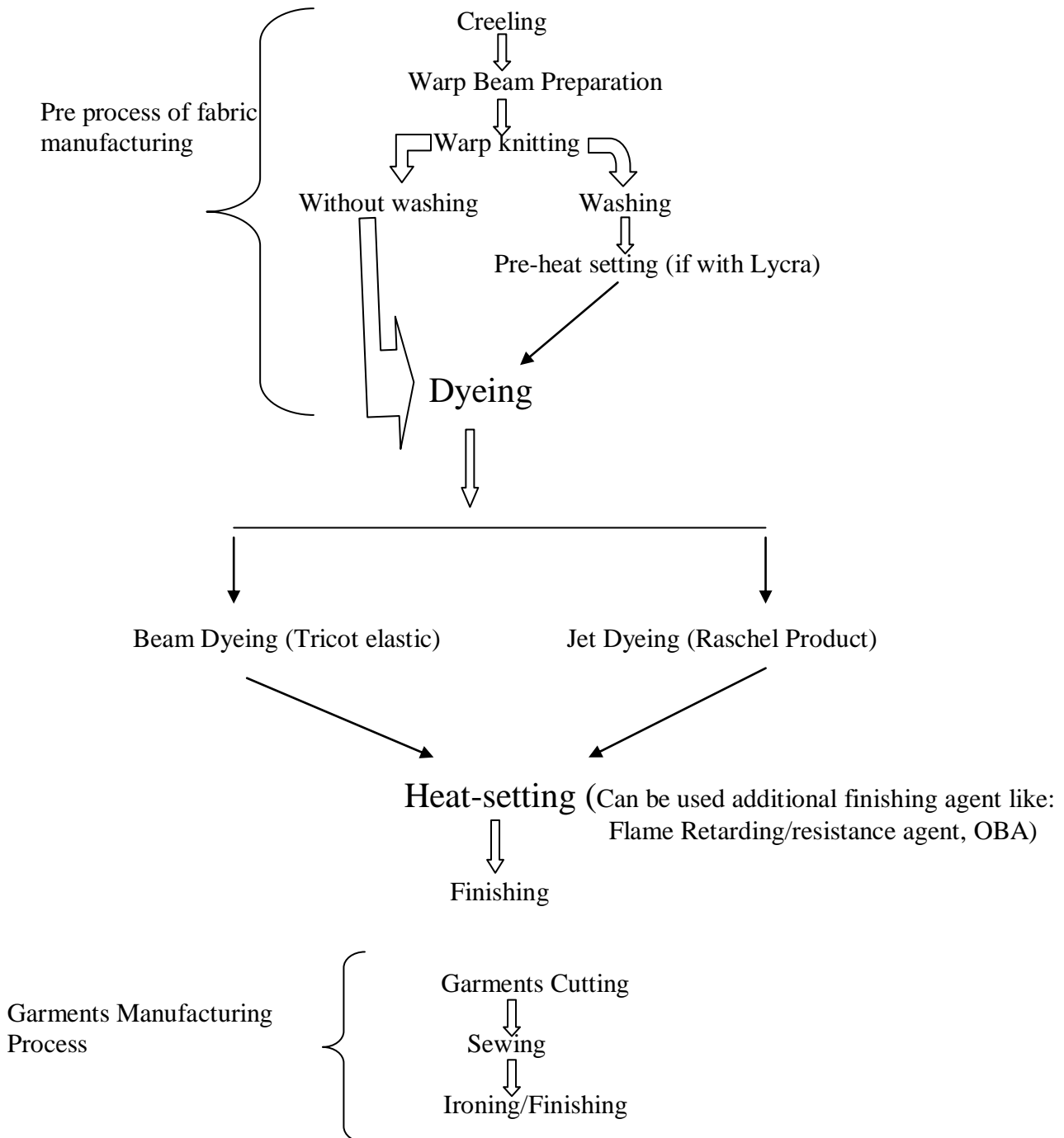
<sup>44</sup> <http://www.libolon.com/polyester-textured-yarn-1.html>

<sup>45</sup> From Karl Mayer, Mr. Roland Baempfer.

## Research Project on Optimization of Warp Knitted Garments Manufacturing

When knitted from 150 denier textured polyester on a Raschel machine or a 21 gauge Tricot machine, a typical type of this fabric is 6.5 ounces per square yard or 220 gsm.

These smooth surfaced fabrics in textured polyester are being used to an increasing extent for men's slacks. Fall plate mechanism may be used to produce fabrics having surface interest effect although care must be taken in designing this to give maximum resistance to snagging. In the below a process sequence for warp knitting is mentioned as:



In case of yarn dyed Warp knitted garments, Warping method is followed by sectional warping.

## **17.0 Seamless garments manufacturing process<sup>46, 47</sup>**

### **1. Yarn inspection and testing.**

#### **Yarns used for DJ / RDPJ warp knitting machine**

Mainly man-made fibers like:

- EL/PA or EL/PES Core yarns 56dtex-100dtex (predominantly used today) – in JB
- PA dtex 33dtex-100dtex (depending on machine-gg)
- PES dtex 33dtex-100dtex
- Elastan 22dtex-78dtex
- Functional Yarns: Coolmax, Thermo cool, Supplex, Thermopile,
- Aero cool X-Tra Dry – Quick drying, moisture management
- Biophyl – modified PES plus natural components, Eco-Polyester
- Magic Silver – Anti microbial
- Yarns with added performance: Novarel Fresh, Novarel PA Aloe Vera

### **2. Warp Preparation:**

DS - Technical details

Warp beam length: 21 - 100 inches

Flange diameter: 21 - 50 inch

Max. Speed: 1.200 m/Min.

Max. Tensile strength: 540 N

Motor: 20 kW

Leveling-roller aggregate: WA-III 4Q

Possible control: DNC – KAMCOS

### **3. Seamless knitting.**

There are three ways to produce seamless garment:

- A. Double needle bar warp knitting - Front needle bar and back needle bar knit the front and back panels respectively, the middle jacquard bar connects them to form the seamless garment.
- B. Computerized flat knitting - The yarn knits on front and back needle beds in turn to form tubular fabric. The complete garment was formed by stitch move.
- C. Body size circular knitting - The cylinder needles knit the tubular fabric. It could be formed garment by simple cut and sew. It can be categorized into single jersey and double jersey.

For this project we will discuss the Double needle bar seamless warp knitting as following steps:

- I. Shape-Leggings Warp-knitted “seams”
- II. Requiring minimum or no making-up specifically placed tight zones for shaping
- III. Follows the contour of the body – perfect fit
- IV. User defined change of lapping (EL)

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- V. Varying stitch density (Multispeed)
- VI. Using of multiple jacquard structures to create various levels of transparency

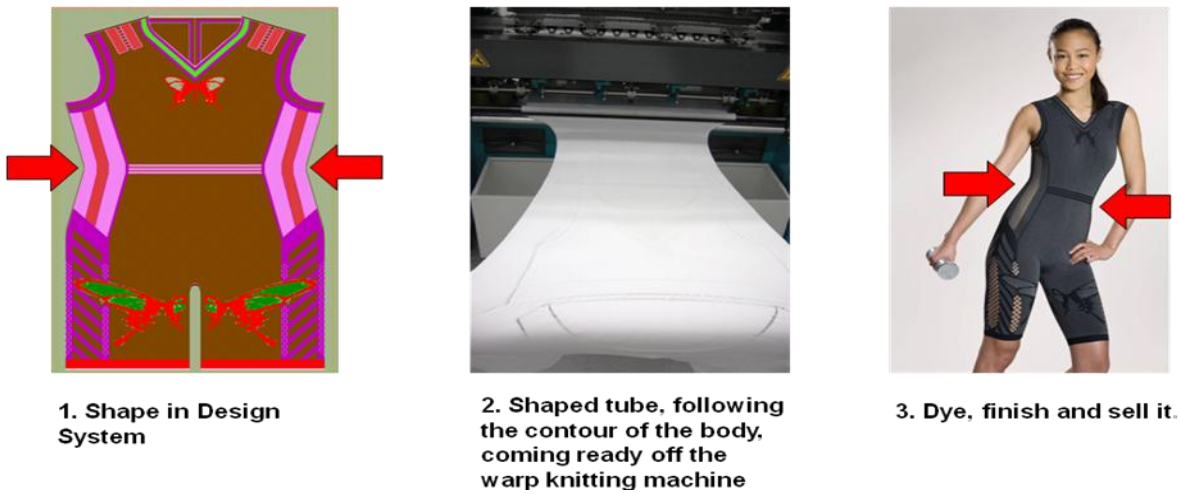


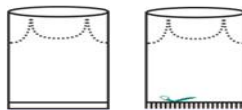
Fig-25: Seamless garments process diagram <sup>48</sup>

- 4. 100% grey inspection of tubes for visual defects.
- 5. Stretch ability test - "Electric Stretch Tester".
- 6. Boarding - steamed and heated to the desired shape.
- 7. Garment dyeing-

Single straight tubes are followed by piece dyeing where tubes knitted into base are followed by jet-dyeing.

### Dyeing systems

#### Piece-dyeing



#### Jet-dyeing e.g. Thies iMaster H2O

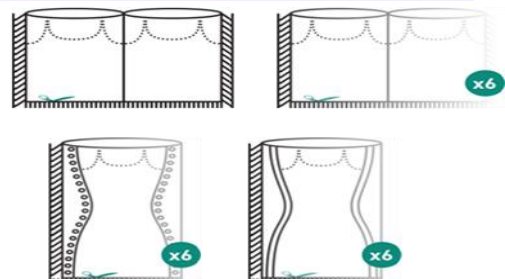


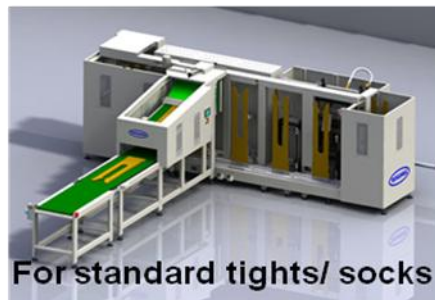
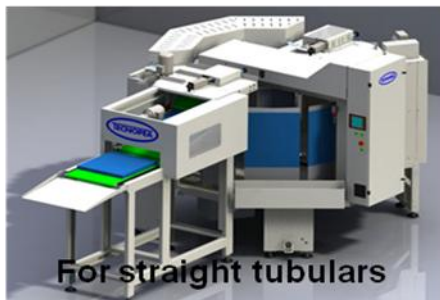
Fig-26: Seamless garments dyeing systems <sup>49</sup>

## 8. Heat Setting: Straight tubes/ single pieces

- Divide the tubes to the required length
- Pull each piece onto a board/ frame
- Finish in a hot air fixing process



Dryer, Steam chamber, Hot air fixing tunnel



## 9. Garment washing - rotating tumble washer/dryer machines.

## 10. Inspection and testing.

## 11. Seaming.

- Gusset seam and leg open elastic for the underwear.
- In seam for the leggings.
- Neck and armhole binding/sleeve attachment.
- Strap/spaghetti attachment for camisoles, sports bras, etc.

## 12. Finishing.

- Pressing (optional).
- Packing.

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<sup>46</sup> <http://www.indiantextilejournal.com/articles/FAdetails.asp?id=4426>

<sup>47, 48, 49</sup> From Karl Mayer, Mr. Roland Baempfer.

## **17.1 In-line processes for seamless goods production**

It is coordinated with warp knitting and finishing technology to perform within four easy stages – warp knit, finish, separate and wear.

### **Step 1: Warp knitting:**

The RDPJ and DJ machine series are perfect for producing seamless goods and items that require very little make-up. The two-bar raschel machines are uniquely flexible. They can be used to produce:

- Tubular shapes having variable diameters along their circumference for e.g. incorporating body contours and thus guaranteeing a perfect fit
- Functional zones in specific locations, having different stretch values and stitch widths, e.g. for producing shape wear or for working borders at the arms, legs or torso
- Seams that are worked directly into the garment
- Open-work, jacquard designs with clearly defined contours located next to plain areas
- Different patterns in the front and back of the component.

The fabric parameters can be set and monitored accurately by the machine's special technical features, such as the Multispeed facility, and other innovative solutions, such as the patterning, yarn feed and fabric take-down systems. For example, the RDPJ 4/2, with a working width of 138" and a gauge of E 24, produced three long-sleeved shirts in a fabric panel. The sequence of articles was defined by two selvages for subsequent mounting in the stenter. A core-spun yarn was processed in the jacquard bar and a standard yarn was processed in the ground guide bars. The fabric was made up of 81% PA 6.6 and 19% elastane. The yarns used to produce the long-sleeved shirts on the RDPJ:

GB2:PA6.6 dtex 40f34

PJB 3-1: PUE dtex44 + PA6.6 dtex 38f34

PJB 3-2: PUE dtex44 + PA6.6 dtex 38f34

PJB 4-1: PUE dtex44 + PA6.6 dtex 38f34

PJB 4-2: PUE dtex44 + PA6.6 dtex 38f34

GB5: PA6.6 dtex 40f34

Spandex consists of at least 85% w/w segmented polyurethane. The international abbreviation is PUE.

### **Step 2: Finishing:**

When relaxing and heat-setting conventional seamless articles take place, the tubes and stockings are normally finished individually. In this case, each separate piece is pulled onto a special frame before heat-setting. These small units consist of a dryer, a steam chamber and a tunnel for hot-air heat-setting. Separate technical options are available for finishing straight-cut tubular items and stockings. However, tubular finishing is not ideal when processing elastane-containing knitted fabrics because of the size of the processing zones available, the achievable temperatures and the process reliability.

BRÜCKNER Textile Technologies can now offer state-of-the-art finishing technologies for after treating high-stretch articles. Tubular, seamless articles can now be finished in the open width on

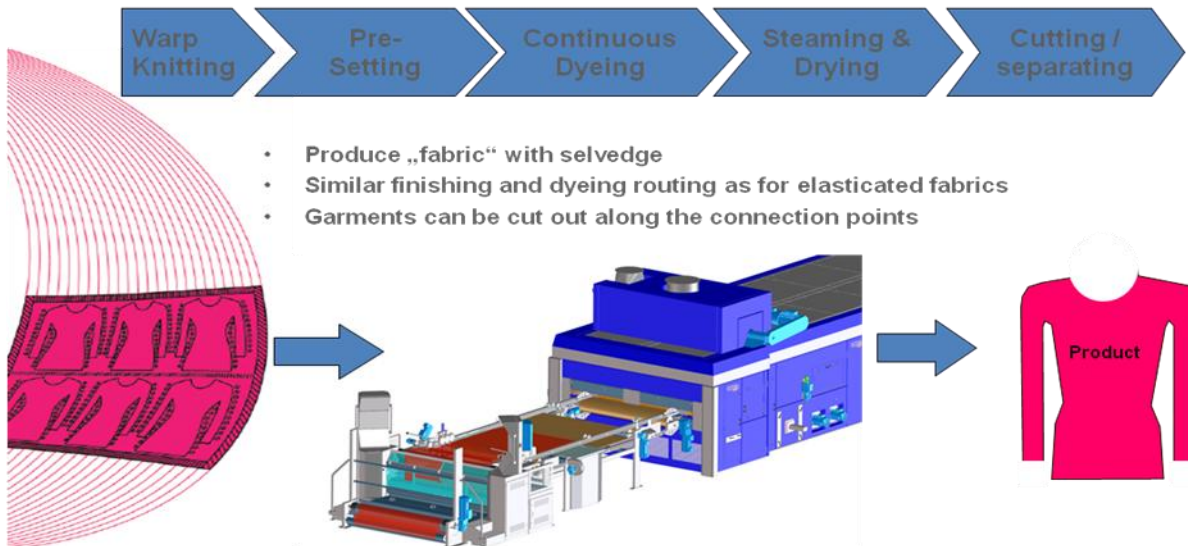


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the stenter with its tried-and-tested process control facilities by incorporating selvedge's into the fabric panel. A pre-heat-setting stage can now be linked up directly to the warp knitting process. The main advantage of doing this that there is fewer tendencies to tear crease or snag. The risk of colour variations caused by excessively high heat-setting temperatures, variations in the elasticity, and fluctuating widths can also be avoided.

### *Heat setting/ Finishing: Tubes knitted into base fabric*

A process developed with Brückner Stenter



The following processing stages include continuous jet dyeing and subsequent heat-setting. The POWER-FRAME VNB stenter works with a perforated belt carrier for supporting the fabric as it is transported through the machine. The belt is also moved vertically at short amplitudes to produce a gentle vibrating effect, which relaxes the fabric and promotes shrinkage in the steamer zone. Further technical features of the machine include:

- An intensive steamer in front of the dryer which, in conjunction with simultaneous relaxation of the fabric on the conveyor belt, results in extremely low residual shrinkage values
- A dryer with a precisely adjustable upper and lower air volume, and uniform distribution of the air and temperature over the entire length and width of the fabric
- Short fabric paths, especially at the entry point of the machine, for preventing the fabric from becoming longer and avoiding stitch distortion
- Pyrometric measurements of the actual fabric temperature for accurate monitoring and control, and also for guaranteeing the reproducibility of the heat-setting time and temperature
- An extremely efficient cooling zone at the exit of the machine for "freezing" the condition of the fabric.

The features of the machine produce a fabric with accurate and reproducible dimensions, since the weight of the fabric in the length and width are optimally uniform. The finishing trials produced minimal differences between the inner and outer fabric panels. The maximum variations were +/- 1

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cm. After subsequent washing at 60°C, the maximum residual shrinkage was 0 to 5%. Some general recommendations for treating the textile have been drawn up on the basis of the trials:

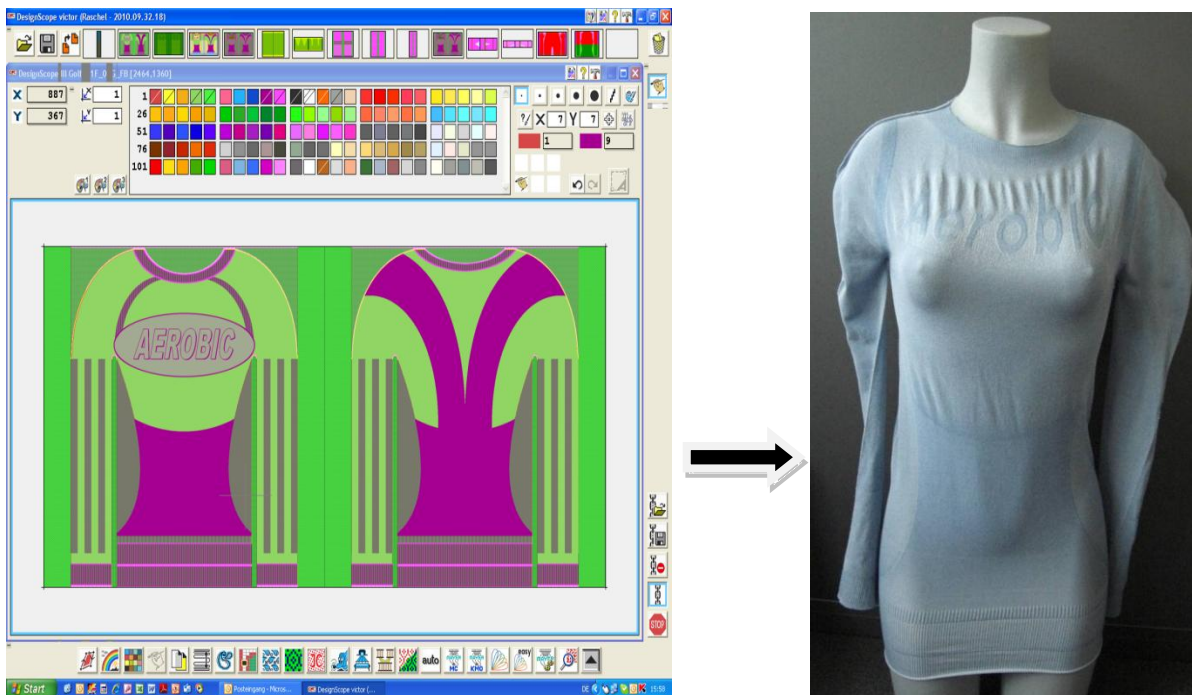
- The fabrics paths should be as short as possible, especially at the entry point of the machine, in order to minimise elongation; support drives for the guide rollers needed are an advantage
- The perforated belt should be positioned close to the entry and exit rollers for avoiding sagging and thus preventing the fabric from becoming longer
- There should be a small gap between the pin bar and the perforated belt to avoid stitch distortion and weight variations, especially around the edges of the fabric.

**Step 3: Separating the garment pieces from the fabric panel**

**Step 4: Wearing**<sup>50</sup>

## 18.0 CAD System

CAD system is a totally-integrated knit production system that allows all phases including planning, design, evaluation and production. Specifically, the loop simulation program permits quick estimation of knit structures without any kind of actual sample making. The program provides an opportunity to see knit problems and to try out diverse knit structures on the computer system before beginning the actual knitting. In the CAD system, each different type of knitting loop is represented by different colored squares. For example, as seen in the following figure, color number 1(violet) indicates a jersey (face loop) and color number 2(green) indicates a reverse jersey (rear loop). Thus, the following violet colored figure shows how a single jersey structure can be displayed on fully fashioned CAD system machine<sup>51</sup>.



**Fig-27: CAD Pattern design and produced garment**<sup>52</sup>.

## **18.1 Pattern Development by CAD system for seamless garments**

- Sketch
- Choosing / placement of designs and structures
- Pattern in real size or scaled down as jpg
- Scanning of pattern
- Preparing color file for CAD program
- Filling of pattern with Drawn information <sup>53</sup>

## **19.0 Seamless Garment Operation Technology <sup>54</sup>**

Seamless garment technology is the advancement in apparel industry which eliminates the fabric laying, cutting and sewing process. Seamless knitting technology has entered the mainstream in the knitwear market at the end of last century. This innovative technology was promising to eliminate post labor work. Moreover, it offered knitwear consumers more comfort and better fit by eliminating seams. Therefore, seamless technology promised great benefits to manufacturers as well as their consumers.



**Fig 28: Seamless Garments <sup>55</sup>**

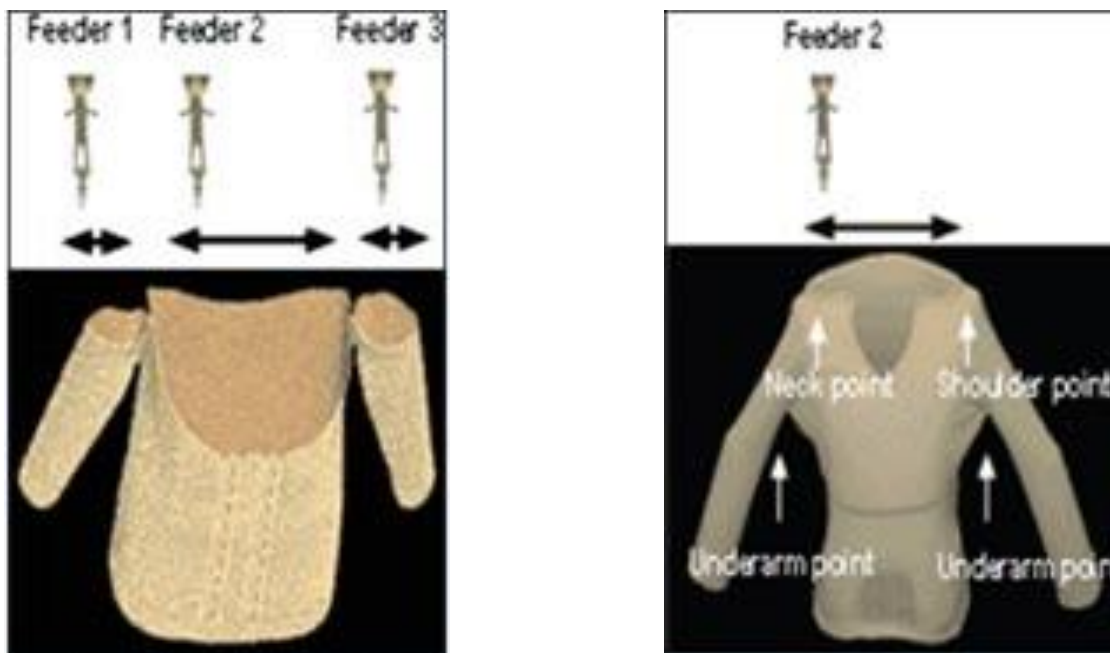
## 19.1 How it works?

- The product is a finished or semi-finished garment with no side seams.
- This technology can directly produce finished products, and lessens traditional process of the production. This leads to saving of production costs up to 40 percent compared to the customary knitting.
- Biggest challenge is to educate the consumer about the range of benefits that seamless garments have to offer.

## 19.2 Technique <sup>56</sup>

Seamless knitting creates a complete garment by several different feeders with minimal or no cutting and sewing processes.

- The garment is knitted into shape, rather than knitting the cloth and then cutting and reassembling the pattern pieces into a garment.
- All the machine needs to do is keep openings for head, arms and legs.
- Knitting the products in one-piece has the benefit that they are seamless at the sides and they have a knitted-in waistband, which does not pinch or roll.



**Fig 29: Technique of seamless garments <sup>57</sup>.**

<sup>50</sup> <http://www.karlmayer.com/internet/en/kmweltweit/4582.jsp>

<sup>51</sup> <http://de.scribd.com/doc/19036381/seamless-garment-technology>

<sup>52, 53</sup> From Karl Mayer, Mr. Ronald Baempfer.

<sup>54, 55</sup> <http://textilelearner.blogspot.de/2013/08/advantages-of-seamless-garment.html>

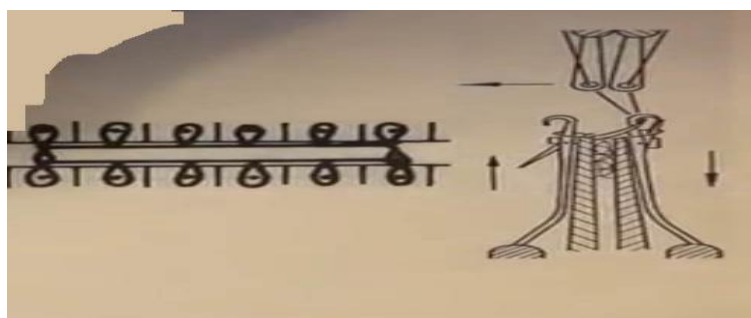
<sup>56, 57</sup> <http://www.indiantextilejournal.com/articles/FAdetails.asp?id=4426>

### 19.2.1 Wale shaping<sup>58</sup>

- The principle involves knitting by increasing or reducing the number of wale internally within a flat piece of fabric by keeping the number of courses same.
- The number of loops diminishes in every row.

### 19.2.2 Course shaping

- The principle involves diminishing or extending successively the length of the courses being knitted alternately.
- Shaping done at one side or both sides.



**Fig 30: Alternate knitting in course and both side shape**

**In course there are two alternate methods:**

- The number of loops diminishes in every row. If the diminution is by more than one loop, small floats occur.
- The number of loops diminishes in every two rows. There are no floats, but small holes can result when knitting on all Wales is recommended.



**Fig 31: The virtual complete garment<sup>59</sup>.**

(This operation technology is mainly used for flat-bed seamless machineries)

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<sup>58, 59</sup> <http://www.indiantextilejournal.com/articles/FAdetails.asp?id=4426>

## **20.0 Quality tests & results**

Fabric and Garment quality tests mainly depend on several criteria's. Quality differences among the weft, warp and seamless garments are mainly on these parameters: GSM test with same count of yarn, Cover Factor, Shrinkage, Bursting Strength, Twisting/Spirality, GSM change before and after dyeing, Pilling test, Shade difference due to construction, rubbing fastness etc. The variation starts due to yarn quality, knitting tension and condition, dyeing and finishing types nevertheless warp knitted fabrics are more stable than weft knits as each needle produces own loop with individual yarn where in weft knitting all needles produce loops within only one yarn. So, in weft one yarn breakage causes long fabric damage.

## **21.0 Benefits of Seamless Garment Technology**

### **21.1 Design Possibilities**

- With our focus on innovation and quality, producers are constantly developing new seamless styles to meet customer's demand.
- Development of new fibers and knitting adaptation are continually evolving. New advancements coming from fiber producers and yarn spinners will continue to provide innovation from the supplier side.
- Based on the structure of the knit, the patterns and construction of the garment cannot be matched with any other non-seamless garment and the ability to combine textures and levels of compression opens up endless possibilities for colored patterns, jacquards, ribbing and detailing.
- There are endless design possibilities with seamless technology, with the variety of different stitches that can be achieved within a single garment, for example a jersey knit can be placed side-by side with a mesh knit, a rib knit, a jacquard knit. This is impossible to do with any other type of knitting process.
- The features of seamless technology benefit the retail store and ultimately the end consumer, who will notice a difference once they try on a seamless garment. Once the consumer wears it, it offers a high-repeat purchase ratio. Consumers are only beginning to understand the benefits of seamless technology.
- Because of the versatile nature of seamless technology, there are infinite opportunities in the market," both locally and internationally. The seamless concept can be applied to underwear, swimwear, control-wear, leisurewear, sleepwear, ready to wear and active wear.

## **21.2 Fit**

- The garments are precisely fitted to the body, producing a smoother, clean look. But in some parts where more compactness is required like in cuffs, the seamless garments have bad performances. These cuffs are better from Flat bed 2x2 Lycra Rib.
- Seamless garments conform smoothly to your individual shape and produce fewer lines under clothes to allow for a more streamline silhouette.
- The softness of seamless knitwear combined with the use of antimicrobial and hydrophilic yarns create the best features for an active wear garment.

## **21.3 Comfort**

- Wearers love seamless garments because they are forgiving, non restrictive and are not binding. The lack of seams provides for improved comfort as the body moves.
- With an increasing demand by consumers for more comfortable and better-looking clothing. Seams tend to pucker up, and tags chafe against the skin. Seamless garments feature knitted in shaping to eliminate bulky elastics and provide enhanced comfort.
- The main seamless products are underwear, outerwear, active wear, shape wear and swimwear, all of which are highly elastic, fine to very fine fabric, made of micro-fibers, required to be very extensible and soft; therefore adding to comfort.

## **21.4 Privileges in Production**

- Besides offering higher comfort and better fit to some consumers by eliminating seams, the innovative technique creates entire garments with minimal intervention of cutting and sewing processes leading to substantial savings in cost and time, higher productivity, quick response, and just in-time production.
- Seamless garments have no waistband failures, no waistband or side seam failures and are more durable due to the high proportion of manufactured fibers such as nylon.
- The broad technical application of selective engagement and disengagement can be adopted sensibly to produce a ready to use customized garment thereby reducing wastage of cloth.
- With traditional production methods, fabric is the starting point for most garments. The fabric is dyed, patterns are cut, and then the pieces are sewn together. If printing or embroidery is part of the design, these are additional steps that take place later in the production process. But with seamless production, there is no fabric. One Italian machine can make the entire product in just minutes; and the machine automatically knits components like waistbands and hems.



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- Seamless garments take 30 percent to 40 percent less time to make than a cut-and-sew version minimizes the traditional labor intensive step of cutting and sewing.

### 21.5 Pricing

- Unlike a regular knitting machine, which produces yards of the same pattern that need to be cut and sewn, the seamless machines produce individual garments from yarn that is fed into the machine-Retails for about 10-15 percent more, because of the specialized equipment involved and the high demand for such limited availability of machinery.
- This benefit is worthy of a price increase, meaning certain part of knitting/apparel category such as intimate, active wear market can be justified due to above listed benefits since some of its features cannot be accomplished in conventional circular knitting or cut & sew method <sup>60</sup>.

### 22.0 Costing

Structure	Elements	Price for 1kg fabric in \$	Wastage%	Approx price/pc T-Shirt
Weft	Raw materials (100% ring Cotton)	3.0	18	\$ 1.8
	Knitting cost	0.14		
	Dyeing and finishing	1.20		
	<b>Fabric cost</b>	<b>4.50</b>		
Warp	Raw materials (100% spun Polyester)	1.65	15	\$ 1.5
	Warp preparation	1.84		
	Knitting cost			
	Dyeing and finishing			
	Fabric cost	3.65		
Seamless	Raw materials		3	\$ 2.5-3.0
	Warp preparation			
	Knitting cost			
	Dyeing and finishing			
	Garment manufacturing cost			

The table shows that seamless garments are still high price due to its high definition machineries.

<sup>60</sup> <http://textilelearner.blogspot.de/2013/08/advantages-of-seamless-garment.html>



### **23.0 Advantages of seamless garments** <sup>61, 62, 63</sup>

Seamless garment knitting makes it possible not only to create several types of tubular formed knitting but also to build diverse design structures on the tubular knitted garments simultaneously. Complete garment knitting offers a variety of benefits in technical aspects as well as in the market demands. For benefits to the market, quick-response production and just-in-time production are possible. The required number of products can be quickly knitted in less time to meet the needs of the customers. It also enables mass customization for many markets. Onal states “Mass customization is the use of technology and management methods to offer product variety and customization through flexibility and quick response. It owes its success partially to computer-based information, design and manufacturing technology”. In certain markets, seamless knitting could be considered for mass customization by rapid design changes according to customers’ requirements through computerized knitting systems (V-bed seamless). Seamless knitting systems may be utilized for sampling prototype and for niche market limited production items.

1. Minimizing or eliminating labor intensive cutting and sewing process.
2. Savings in production times and cost.
3. Minimal yarn consumption.
4. Higher productivity.
5. Multi-gauge knitting (Multi-gauge machines minimizes the production. So, Multi-gauges are now decreasing for warp seamless machines)
6. Lightness and softness.
7. No bulky and irritating stitches/seams.
8. More constant product quality.
9. Better trim ability for finished edge lines.
10. Better look, better fit and more comfortable.
11. More creative knitting possibilities for designers.
12. Quick-response production for size and pattern changes.
13. Just-in-time production.
14. Mass customization.

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15. Freedom of body movement: generally the seam portion of any garment is not having the same elasticity as compared to the body fabric, so the difference in elasticity will affect the free body movement. Since the seamless garment doesn't have any seam in its structure, this problem has been eliminated.

16. Wider range of fit for different range of body shapes: in a single garment measurement can suitable for wider range of fit for different range of body shapes because of its higher elasticity. Thus the high repeat of orders and low returns occur for the retailers.

17. Inherent softness: there are no bulky and annoying stitches at the underarm points, shoulders and neck lines, which may cause irritation to the wearer, since the garment having seam free structure it provides the soft feel only.

18. It reduces labor cost: due to the elimination cutting and sewing process it is obvious to reduce more labor involvement.

A Production statistics are given as below for Cifra:

- 12,000 Ends of yarn for running single machine
- 4000 knot/stitches for a T-shirt
- 40 km of yarn for a T-shirt
- More than 4000 ends of yarn for long sleeves shirt.

19. Seamless 400% maximum elasticity in tension opens up possibilities for underwear.

20. Natural comfortness when wearing

21. No skin irritation, as no seams in the range of motion

22. Moderate pressure will reduce fatigue controlling the vibration of muscles

23. Tubes follow the CONTOUR of the body – improved FIT

24. Joining different diameters of tubes within ONE garment, coming from ONE machine

25. No laddering

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<sup>61</sup> <http://www.fibre2fashion.com/industry-article/pdffiles/Three-Dimensional-Seamless-Garment-Knitting.pdf?PDFPTOKEN=d49febc36a060e80ffd710fa34c362c8aea2c481>

<sup>62</sup> <http://www.indiantextilejournal.com/articles/FAdetails.asp?id=4426>

<sup>63</sup> <http://www.cifra-spa.net/en/products/warp-knitting-seamless-wks>

## **24.0 Disadvantages of seamless knitting**

1. There are technical limitations in seamless technique to knit every garment type/shape that are currently produced by cutting and sewing. The main problem has been the fabric take-down in keeping equal tension of each loop (i.e., stitch).
2. Another problem is caused during alternate needle selection, which makes fabrics more open and less elastic than conventional fully-fashioned garment. This problem (mainly on V-bed seamless) occurs mainly in the welt or the cuff areas.
3. Bad elasticity occurs in cuff and waistband zones. In the same machine and same time, it is quite difficult to provide higher GSM and high elasticity. So, the warp seamless machines give bad fitting on cuff and waistband zones than the normal 2x2 Lycra Rib or other cut and sewn cuff and waistband.
4. Crotch point and armpit is not also well shaped as cut and sewn garments. For warp seamless, it is normally round rather than pointed.
5. The machines used for manufacturing seamless garment are costlier and more skilled operators are required.
6. Warp knitted seamless machines are available only for synthetic or blended fibers. But 100% natural fibers are not still accessible to them.
7. A fault during knitting (particularly a hole or a barre), damages the whole garment.
8. While lightweight, next-to-skin garment score advantage points for comfort, this is slightly less important for outerwear garment where the seam can become a style/ fashion feature<sup>64</sup>.

## **25.0 Figure out of future possibilities of Warp knitting**

Warp knitted products are developing day by day. The most common fields in apparel sector are sportswear, swimwear and lace. These ranges from normal jersey wear to functional wear. Moreover functional tricot knitted sportswear with special properties and active Performances like:

- Coolmax - high moisture.
- Wicks sweat away from your body, quick dry and easy clean.
- Keeps cool, dry and comfortable.
- Lightweight, soft and breathable.
- Wind-proof and water-proof.
- Odor-inhibiting effects by SILVER+ technology
- STAY COOL: Combination of UV protection and
- Prevent muscles from cooling
- Ventilation inserts under the arm, etc. are used mainly for vigorous purpose and comfort ability.

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In addition to sportswear and active wear, there is also growing interest in moisture management fabrics from the flame retardant apparel market as Performance Apparel.

Generally, the most effective moisture management fabrics are high-tech synthetic fabrics which are made from polyamide or polyester microfibers. These are lightweight, are capable of transporting moisture efficiently, and dry relatively quickly. Moisture management capabilities can also be enhanced by using certain finishing processes, by varying the fabric or fiber construction, or by using a blend of fiber types. Multi-functional high-tech breathable finish, which repels moisture on the outside and transports moisture quickly from the inside. This finish is highly breathable, less susceptible to soiling and dries very fast. Functional fabrics transport perspiration away from the skin and breathability is one of the determining factors in the comfort level of garments.

The number of polyester-based moisture management fabrics on the market has also increased dramatically in recent years, and includes Capilene from Patagonia and Polartec's Power Dry. As manufacturers of sports and active outdoor wear strive to improve the functionality of their collections, the future will see further developments in the field of moisture management fabrics. For example, the area of nano-fibers looks set to revolutionize the moisture management market. In addition, the next generation of "smart" textiles could see the development of fabrics which are able to respond to changes in the environment by adjusting their pore size or thickness to allow moisture through<sup>65</sup>.

Polyester and Polyamide fibers are very tear-proof and abrasion-resistant and absorb little moisture (thus good transport of moisture away from the body) and are stretchy, crease-free, but also prone to pilling. Polyamide has the highest resistance of all textile raw materials (also when wet) and is very stretchy. Polyester has excellent return conduct thanks to the rippling property and is very light. Polyester also retains its shape and is colorfast, as well as resistant to sweat and UV-rays (lightfast). Polyester has a high melting point and transfers can therefore be printed on this material). So on the bases of demand for polyester and polyamide, Warp knitted tricots are getting better market in these fields.

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<sup>64</sup> <http://www.indiantextilejournal.com/articles/FAdetails.asp?id=4426>

<sup>65</sup> [http://defense-update.com/products/m/moisture\\_management\\_fabric.htm](http://defense-update.com/products/m/moisture_management_fabric.htm)

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**Fig-33: Tricot warp knitted mesh fabrics**  
**Comp.: 100% textured-polyester, ultra-breathable**



**Fig-34: Warp Knitted seamless breathable Ladies T-Shirt**

New addition of natural and synthetic blend fiber to warp yarn brings also high possibility to the casual wears. If the machine cost of seamless knitting machines can be minimized, warp knitting and seamless garments could provide vast popularity to the manufacturers as well as to the customers.

### **26.0 Obstacles to Warp Knitting Technology Developments**

- Higher Machine cost
- Investment cost for a composite project with knitting, dyeing, finishing and garments is higher than weft garments project.
- Risk of new product launch
- Technology idea of new manufacturers.
- Operation knowledge to the operators or technicians because warp knitters are required to be more high skilled.

### **27.0 Project Results**

1. Machine price for warp seamless garments are too high. So still per piece garment cost is also higher than cut & sewn garment.
2. Due to labor sensitive, once less price seamless machines could deal with low price garments.
3. Warp Knitted garments are for synthetic fiber. So, they are still only suitable for sportswear and swimwear. Now adapting some blended fiber that could lead them to casual wear.
4. Due to faster production it has high possibilities to install high productive plants in immediate future all over the textile fields

## **28.0 Conclusion**

For seamless garment knitting, the machines have the capability not only to create shaped knitting, but also to make various knit design structures in the complete garment by utilizing alternate needle selection. The seamless techniques is pioneering in apparel markets because for its smooth fit, comfort, invisibility and easy care properties. As a result, it is believed to offer savings in terms of production times and cost, and it minimizes yarn consumption.

In addition, seamless garment knitting provides more consistent and homogeneous product quality, which gives lightness and comfort in the garment. It also offers knit designers more creative knit possibilities. The trends worldwide suggest that seamless garment is becoming popular among masses especially with the youth. There is a potential for seamless garment to hold 50% of the industry's sales within next 10-years by providing sectional and training facilities and adding versatile design features.

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<sup>2</sup> From Karl-Mayer, Mr. Roland Baempfer

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<sup>4</sup> From Karl-Mayer, Mr. Roland Baempfer

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